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DDD and Single-Lead VDD Pacing: Evaluation of Atrial Signal Dynamic Changes

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Summary

Background: Single-lead VDD pacing systems are an alternative to conventional DDD pacemakers in patients with atrioventricular (AV) block and normal sinus function.

Hypothesis: The aim of this study was to assess changes of P-wave amplitude occurring in dynamic conditions in two groups of patients with a single-lead VDD and with a DDD pacing system, respectively.

Methods: Twenty-eight patients with second- or third-degree AV block and normal sinus function were enrolled prospectively into the study. Seventeen patients were implanted with a single-lead VDD pacing system and 11 with a DDD pacemaker. Patients were evaluated at 3 months (all patients) and at 6 months (26 patients) at supine and in dynamic conditions (postural changes, hyperventilation, and during exercise).

Results: Mean P-wave values at supine were 1.92 ± 1.10 mV at 3 months and 1.76 ± 1.01 mV at 6 months for VDD systems, and 4.63 ± 2.18 mV at 3 months and 4.58 ± 2.80 mV at 6 months for DDD pacemakers. In dynamic conditions, P-wave amplitude changes compared with supine condition ranged between −74 and +226% in VDD, and between −53 and +138% in DDD; however P-wave amplitudes showed no significant changes compared with baseline. Moreover, changes in atrial signal amplitudes did not occur randomly, and in both systems P-wave amplitudes remained significantly correlated with supine values.

Conclusions: A wide range of P-wave amplitude variations occurs in different postural conditions or during exercise, both with single-lead VDD and DDD pacing systems. However, with appropriate programming of atrial sensitivity based on supine values, constant atrial tracking can be maintained.

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Introduction

Maintenance of atrioventricular (AV) synchrony by dual-chamber pacing results in hemodynamic and symptomatic benefits compared with single-chamber ventricular pacing.[1] The use of single-lead VDD pacing systems in patients with AV block and normal sinus function is increasingly accepted and may be an alternative to implantation of a DDD pacing system.[2,3] Either in VDD or DDD pacemakers, appropriate programming of atrial sensitivity is based on P-wave measurements performed at implantation or during follow-up, using the telemetric functions available in most recent pacemakers. Reports in the literature[4,5] have shown a significant decrease of P-wave amplitudes during exercise for DDD or VDD pacing systems,[5,6] and P-wave undersensing during exercise has been reported as well.[4] Moreover, the atrial signal amplitude may have consistent variations according to body posture in both single-lead VDD and DDD pacing systems.[6,7] The aim of this study was to assess the changes of P-wave amplitude, occurring in dynamic conditions (postural changes, hyperventilation, and during exercise) in two groups of patients, with a single-lead VDD pacing system and with a DDD pacing system with passive leads, respectively. Atrial electrograms were evaluated in all patients by a programmer allowing real time P-wave measurement of intracardiac electrograms (during dynamic conditions).

Methods

Twenty-eight patients with second- or third-degree AV block and normal sinus function were enrolled into the study. Seventeen patients (age 74 ± 7 years, range 65–89) were implanted with a VDD pacing system, and the indication was second-degree AV block in 6 cases and third-degree AV block in 11 cases. These patients were implanted with a VDD pacing system including as device AddVent™ 2060LR (Pacesetter Inc., Sylmar, Calif., USA) and as endocardial lead AV Plus™ 1328C (Pacesetter Inc.). AddVent 2060LR is a multiprogrammable VDD pacemaker with programmable VVI

rate-responsiveness. Atrial sensing is bipolar, while ventricular pacing and sensing are programmable as either bipolar or unipolar. The endocardial lead AV Plus is an endocardial quadripolar catheter in which two atrial rings of 32 mm^2 each, with an interelectrode distance of 12 mm, provide bipolar atrial sensing by floating in the atrium. Leads with the distal atrial ring placed at a distance of 13 cm from catheter tip were employed in all cases.

Eleven patients (age 75 ± 9 years, range 46–84) were implanted with a DDD pacemaker, and the indication was second-degree AV block in 5 and third-degree AV block in 6 patients. Patients were implanted with a Paragon™ III 2314L (Pacesetter Inc.) in two cases, with a Synchrony™ III 2028L (Pacesetter Inc.) in three cases, and with a Trilogy™ DR+ 2364L (Pacesetter Inc.) in six cases, coupled with passive tined atrial and ventricular bipolar lead. Atrial leads were Membrane™ 1420T in seven cases and Membrane™ 1421T in four cases. The two groups of patients (implanted with VDD or DDD systems, respectively) were comparable with regard to age, etiology, and clinical profiles.

For inclusion in the present study, a measured P-wave amplitude of at least 0.8 mV (preferably > 1.2 mV) was required for VDD pacing and of at least 1.5 mV (preferably > 2 mV) for DDD pacing at implantation.

After implantation and at predischarge visit, pacemaker programming was carried out according to usual guidelines for ventricular sensitivity and output. Rate responsiveness was not activated. Atrial sensitivity was kept at 1/3 of sensitivity threshold for VDD and for DDD pacemakers, as evaluated by telemetry in supine conditions at predischarge, at 3 and 6 months evaluation (atrial sensitivity can be programmed from 0.1 to 5.0 mV for VDD and from 0.5 to 5 mV for DDD). Atrial sensitivity threshold was assessed by the semiautomatic test provided by APS II 3004 programmer (Pacesetter Inc.), consisting in a stepwise decrease of sensitivity until loss of sensing is confirmed by the operator.

During follow-up, patients were followed according to usual guidelines; moreover, at 3 and 6 months after implantation, patients were submitted to P-wave sensing evaluation in dynamic conditions. Telemetric measurements were made with the programmer, and four P-wave electrograms (bipolar intracavitary electrograms) were recorded at 100 mm/s, with appropriate gain setting, in four different stages: supine, standing, hyperventilation, and peak exercise. Subsequently, the average value among four P waves recorded was calculated. For these tests, the pulse generator was programmed at 50 beats/min to allow spontaneous atrial activity; the upper tracking limit was set at ± 130 beats/min and the postventricular atrial refractory period at 300 ms. The postventricular interval was programmed at 100 ms in order to check appropriate atrial sensing by ventricular activation guided by atrial tracking. The rate-responsive function was programmed passive. Exercise testing was performed by a bicycle ergometer employing a protocol with steps of 25 W/2 min. The test was symptom limited, and during the test the electrocardiogram was continuously monitored; strips were recorded every 1 min and blood pressure was checked every 2 min.

Data Analysis

For statistical analysis, the analysis of variance (ANOVA) test for repeated measures was employed to analyze the intrasubject variations in P-wave amplitude. Correlations between P-wave values recorded in different conditions were calculated by Pearson's test. Statistical significance has been assumed at $p < 0.05$.

Results

All 28 patients enrolled were evaluated at 3 months, while at 6 months 2 patients implanted with DDD could not be evaluated for worsening of clinical conditions and for substantial changes in clinical status (e.g., development of atrial fibrillation or sustained ventricular arrhythmias). Figure 1 shows P-wave amplitudes recorded in supine and standing conditions, during hyperventilation, and at maximum exercise. In each patient group (implanted with VDD or DDD pacemakers) the changes in P-wave amplitudes in the above-mentioned conditions did not reach statistical significance either at 3 or at 6 months. In patients implanted with VDD pacemakers, atrial sensitivity was set between 0.1 and 1 mV, and in 75% of patients it was programmed < 0.4 mV. In patients implanted with a DDD pacemaker, atrial sensitivity was set between 0.75 and 1.5 mV. By this programming, constant atrial tracking was maintained in all conditions. In patients implanted with a VDD pacemaker, atrial rate increased during exercise from 70 ± 11 to 118 ± 9 beats/min at 3 months (mean exercise time 7 min) and from 73 ± 16 to 119 ± 17 beats/min at 6 months (mean exercise time 6 min). In patients implanted with DDD pacemakers, atrial rate increased during exercise from 75 ± 10

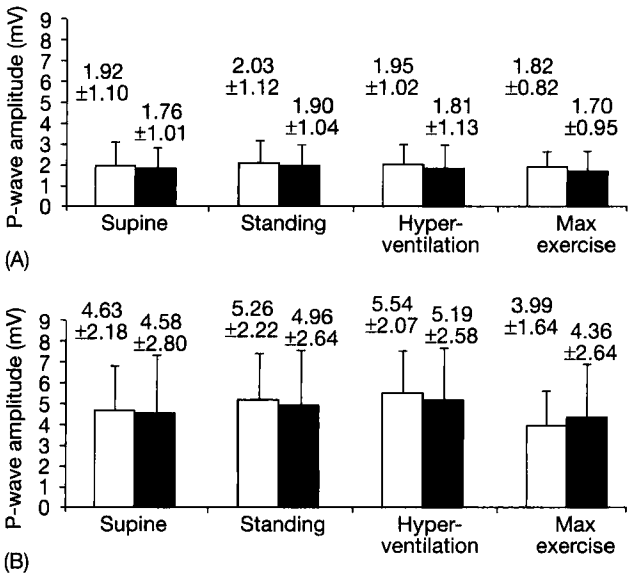

FIG. 1 Mean values (± standard deviation) of P-wave amplitudes (mV) in (A) VDD (n = 17) and (B) DDD (n = 11 at 3 months and n = 9 at 6 months) at supine and in three different dynamic conditions. □ = 3 months, ■ = 6 months.

TABLE I Mean % changes in P-wave amplitudes in different conditions [range of % changes] and correspondent correlations at Pearson's test

	% Changes		Correlation	
	3 Months	6 Months	3 Months	6 Months
VDD				
Standing vs. supine	20 ± 59 [−71/+178]	9 ± 37 [− 36/+128]	r = 0.76[a]	r = 0.91[c]
Hyperventilation vs. supine	13 ± 40 [−72/+93]	4 ± 52 [−57/+168]	r = 0.74[a]	r = 0.80[a]
Max exercise vs. supine	13 ± 64 [−74/+215]	4 ± 64 [−64/+226]	r = 0.73[a]	r = 0.64[a]
Max exercise vs. standing	−2 ± 28 [−60/+44]	− 9 ± 29 [−53/+43]	r = 0.69[b]	r = 0.81[a]
DDD				
Standing vs. supine	22 ± 40 [−18/+122]	14 ± 23 [−11/+55]	r = 0.91[a]	r = 0.97[a]
Hyperventilation vs. supine	32 ± 50 [−18/+138]	22 ± 29 [−28/+66]	r = 0.84[b]	r = 0.92[a]
Max exercise vs. supine	−4 ± 32 [−47/+61]	−2 ± 12 [−19/+11]	r = 0.73[d]	r = 0.96[a]
Max exercise vs. standing	−21 ± 18 [−53/+5]	−14 ± 10 [−28/+2]	r = 0.77[c]	r = 0.98[a]

[a] $p < 0.001$.
[b] $p = 0.001$.
[c] $p < 0.01$.
[d] $p = 0.01$.

to 125 ± 19 beats/min at 3 months (mean exercise time 6 min) and from 79 ± 20 to 129 ± 20 beats/min at 6 months (mean exercise time 6.5 min). A wide range of P-wave amplitude variations was found comparing recordings in supine, standing, hyperventilation, and at maximum exercise for both VDD and DDD patients, as shown in Table I. This finding suggests marked intersubject variability. However, significant correlations (from $p = 0.01$ to $p < 0.001$) were found at Pearson's test between absolute P-wave values recorded at supine and those recorded in the three other conditions (Table I). Also, P values recorded during exercise and in standing conditions showed an high degree of correlation (Table I).

Discussion

In this study, changes in P-wave amplitudes, occurring in different postures, during hyperventilation and exercise, were analyzed in two groups of patients implanted with VDD or DDD pacemakers. The two pacing systems differ in the way they sense the atrial signal (by a floating atrial dipole in VDD systems, by a passively fixed bipolar lead in DDD systems). Previous reports analyzed the changes occurring in different postural conditions or during exercise in heterogeneous populations implanted with DDD systems and unipolar or bipolar atrial leads with active or passive fixation,[4] or in homogeneous populations implanted only with VDD pacing systems.[5,6] This study shows that recorded P-wave amplitudes show a wide range of variations, with marked intersubject variability, both with VDD and DDD pacing systems. However, with appropriate programming of atrial sensitivity, based on supine measurements, constant atrial tracking was maintained, indicating that the observed changes were of minor clinical significance. These observations are in contrast with a previous report[4] in which a high incidence of atrial undersensing during exercise was found. In that paper[4] the methodology for programming atrial sensitivity and the extent of programmability were quite different from those followed in this study. Although several factors may condition P-wave amplitude such as changes in the electrical vector, changes in cardiac chamber volume, effects of catecholamines, and heart rate,[7] the atrial signal changes do not seem to occur randomly according to the present study, because P-wave amplitudes recorded during standing, hyperventilation, or exercise remain significantly correlated with supine values. A limitation of our study could be that P waves have been evaluated by electrograms (EGMs) and not by the sensing circuit of the device. However, a previous paper[8] showed that P-wave amplitudes derived by EGMs correlate strictly with measurements made by the sensing circuit.

Conclusions

In conclusion, a wide range of P-wave amplitude variations occurs in different postural conditions or during exercise, both with single-lead VDD and with DDD pacing systems. However, with appropriate programming of atrial sensitivity based on supine values, constant atrial tracking can be maintained. Moreover, changes in atrial signal amplitudes do not occur randomly, and in both systems P-wave amplitudes remain significantly correlated with supine values.

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